View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Elsevier - Publisher Connector

A phantom with known geometry should be used, either including markers with known relative coordinates or test objects with known shapes and volumes. The design of the phantom will be depend of the modality to be tested.
For ultrasound imaging the AAPM Task Group 128 includes a list with 8 elements of a phantom that allow for all the recommended tests [1]. It is referred to a commercial phantom that include nylon monofilaments in a N-shaped pattern and spherical and non-spherical volume in order to test key imaging parameters such as depth of penetration, axial and lateral resolution, distance, area and volume measurements and geometric consistency.
Roué et al used a commercial PMMA phantom with 25 stainless steel markers with known relative position to check the geometric accuracy of CT and conventional x-ray imaging [2]. A phantom including several inserts with different density can be used to check the volume reconstruction accuracy for CT. Several commercial phantoms are available.
It is well known that geometrical distortions can frequently occur in MR images. The magnitude of the distortions should be investigated by using phantoms with markers or tubes filled with for example Cu2+-doped water solution. Additional, the influence of an applicator should also be investigated since for example the presence of a titanium applicator may produce geometric distortion in a high field MR machine.
The slice thickness will also influence the ability to reconstruct the geometry correctly. With too large distance between the slices the partial volume effect will influence the accuracy of the volume reconstruction [3]. On the other hand, de Brabandere et al showed that too small distance between the slices decreased the accuracy of seed detection in a dedicated phantom with agarose gel and 60 iodine seeds with known position using MR imaging [4].
References
1. Pfeiffer D et al. AAPM Task Group 128: Quality assurance tests for prostate brachytherapy ultrasound. Med Phys 2008;35:5471-5489.
2. Roué A et al. The EQUAL-ESTRO audit on geometric reconstruction techniques in brachytherapy. Radiother Oncol 2006;78:78-83.
3. Kirisits C et al. Accuracy of volume and DVH parameters determined with different brachytherapy treatment planning systems. Radiother Oncol 2007;84:290-297.
4.De Brabandere M et al. Accuracy of seed reconstruction in prostate postplanning studied with a CT- and MRI-compatible phantom. Radiother Oncol 2006;79:190-197.

SP-0023
Dose verification
K. Tanderup[1]
[1]*Aarhus University Hospital, Department of Oncology, Aarhus C, Denmark*

Any radiotherapy delivery is associated with uncertainties and with risk of misadministration/error. Misadministration/error refers to treatment incidents/accidents which can be prevented, while uncertainties can only be controlled to a certain degree and the residual variation must be accounted for through tolerances and treatment margins. Patient safety through prevention of radiation dose misadministration is highly prioritised and several authorities and societies worldwide are focusing on radiation safety and medical events. In 2004, the International Commission of Radiation Protection (ICRP) reported an analysis of 500 radiation events in BT. This investigation and others have shown that a significant share of radiation events are caused by human errors related to the manual procedures of BT. Verification in radiation therapy means the whole process of proof that planned dose is delivered to the patient within a specific level of accuracy. During the last two decades enormous developments and technological innovations in the field of external beam radiotherapy (EBRT) treatment verification have taken place. These developments have focussed on imaging technologies for 2D and 3D (and very actually also 4D) localization and anatomy reconstruction under treatment delivery conditions. Striking innovations have been imaging technologies such as flat panel detectors, cone beam CT (CBCT), and most recently MRI, which is integrated with the linear accelerators. The combination of 3D-imaging techniques and dose measurements enables the estimation of the daily 3D-dose delivery in the patient anatomy. In contrast, on-board or real-time treatment verification of BT is currently not performed, simply because adequate tools are not available. There is currently a striking unbalance between the availability of treatment verification technology for EBRT and BT, and consequently a different level of safety. Adding even further to this unbalance, BT is related with higher risk of major dose misadministration than EBRT, since BT involves: 1) more manual procedures (e.g. assembly and implantation of applicators, catheter reconstruction, and guide tube connection), 2) mechanical equipment with a higher susceptibility to malfunction (e.g. source cable drive and applicators), 3) more frequent application of hypo-fractionation schedules, and finally 4) steeper dose gradients. New methodologies for treatment verification are highly warranted. Dose and source geometry are closely linked entities in brachytherapy. Dose calculation with TG43 is the current standard of dose calculation in brachytherapy, and has excellent accuracy in most clinical scenarios. TG43 is based on geometry. Given a direct correspondence between brachytherapy source geometry and dose, a geometric verification is nearly equivalent to a dosimetric verification. There are only few error scenarios where source geometry would be correct, but not dosimetry – e.g. source mis-calibration. Therefore several novel “on-board” treatment verification tools are focused on verification of geometry: EM tracking of catheters, flat panel monitoring of source progression, fluoroscopy, and real-time in vivo dosimetry. Given the source geometry is correct, the next important step is to secure that the relation between sources and anatomy is correct. This last step is typically explored with imaging. Combinations between different verification tools may be the way to proceed to reach a higher level of treatment verification in brachytherapy which address geometry, patient anatomy and consequent dose delivery to the patient. The presentation will outline current developments in “on-board” treatment verification tools. The table below shows the current status of treatment verification in EBRT and BT, and indicates visions that can bring brachytherapy treatment verification forward.

Symposium: Robust and accurate functional MRI for radiotherapy

SP-0024
Needs and technical requirements for functional MRI in radiotherapy
U.A. Van der Heide[1]
[1]*The Netherlands Cancer Institute, Department of Radiation Oncology, Amsterdam, The Netherlands*

Anatomical imaging with T1 and T2-weighted MRI is increasingly used in combination with CT for precise delineation of tumors and normal structures. MRI also offers functional techniques, such as diffusion-weighted MRI (DWI) and dynamic contrast-enhanced MRI (DCE-MRI). These can be applied in radiotherapy for tissue classification, monitoring of treatment response as well as for dose painting. In the diagnostic setting, these sequences are often part of routine scanning protocols. However, as for anatomical MRI sequences, there are some specific issues that need to be considered when applying these techniques in radiotherapy. For image registration with the planning CT, patients need to be scanned in treatment position. If the functional images are used for target delineation, their geometrical fidelity needs to be verified. In particular diffusion-weighted MRI is prone to geometrical distortions. Methods to reduce these distortions will be discussed. The spatial resolution of functional imaging tends to be lower than that of anatomical imaging. Although acquisition with small imaging voxels is feasible, this doesn’t mean that the functional quantity (apparent diffusion coefficient for DWI and tracer kinetics parameters for DCE-MRI) can be reliably determined in a

single voxel. Test-retest measurements are a method to determine the smallest volume for which a reliable measurement can be obtained. A key asset of functional imaging is the capacity to measure physical quantities in tissue rather than contrast. In particular for longitudinal studies, monitoring treatment response, or in multi-center studies, this is critical. For radiotherapy dose painting it is necessary to know which threshold should be used to define a subvolume of the target for dose escalation. In the presentation, various quantitative methods and their reliability will be discussed.

SP-0025

Variation in DCE-MRI methodology and its implications for radiotherapy

A. Garpebring[1]
[1]*Umeå University, Department of Radiation Sciences, Umeå, Sweden*

Dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) is a technique based on rapid acquisition of a series of images depicting the uptake of a contrast agent (CA) in tissue. Through mathematical modeling of the CA's influence on the MR signal and the distribution of CA in the tissue, physiological parameters can be obtained on a voxel by voxel level.
These parameters, which for instance reflect flow, vessel integrity, cell and vessel density, are highly relevant in cancer treatments such as radiotherapy (RT). Several studies have shown that pretreatment parameter values as well as changes during RT can be correlated with outcome. However, drawing firm conclusions on the practical value of DCE-MRI in RT is currently difficult.
The reason for this difficulty has its roots in the complexity of performing a DCE-MRI study. Obtaining accurate quantitative parameter values reflecting primarily the physiology of a tumor requires advanced imaging as well as complicated post processing. Unfortunately, even though state of the art acquisition and analysis is performed it is likely that influences from the precise acquisition settings and the analysis tools remain in the final result. Hence it is crucial that all variations during a study is minimized to maximize the sensitivity.
Not only is it of great importance to reduce the variability within a study, ideally this should also be the case between studies. But here we have a significant issue. There are a large number of unavoidable trade-offs in DCE-MRI. For instance between spatial and temporal resolution and between accuracy, complexity and robustness of the analysis. Usually each group performing a study make their own decision on where to compromise and what parameters to evaluate. Although this may be optimal in each study it is problematic when drawing conclusions on the overall value of DCE-MRI in RT.
Of this reason several authors are calling for standardization of DCE-MRI acquisition and analysis. One organization that has responded to this call is the Quantitative Imaging Biomarkers Alliance (QIBA) which has published guidelines for standardizing DCE-MRI. In a comparison of methodology in studies employing DCE-MRI in RT the results are mixed. Overall, the technical quality of studies, measured as compliance with QIBA guidelines, is improving with time. However, the spread is also increasing. Hopefully, in the future more people will adhere to the attempts to standardize DCE-MRI and thus enable more homogenous data which can be used for better answering how DCE-MRI can be employed to improve RT.

SP-0026

Importance of b-value selection and geometrical accuracy in DW-MRI for radiotherapy

M. Lambrecht[1]
[1]*University Hospital Gasthuisberg, Department of Radiotherapy and Oncology, Leuven, Belgium*

Over the last decade, Diffusion Weighted MRI(DWI) has emerged as a promising imaging technique in the field of radiation oncology.
The ability of DWI to assess a tissue's microstructure makes it potentially very valuable in tumor characterization, delineation, detection of pathological lymph nodes, response prediction and response evaluation.
However, acquisition, analysis and interpretation of the images is far from straightforward. The imaging technique is prone to distortions interfering with the accurate geometrical localisation and quantification of the tissue of interest.
Furthermore quantification is heavily influenced by the choice of machine parameters, making reproducibility an important issue.
Overcoming these problems is of the utmost importance to move DWI out of the realm of research and into daily practice.
In this talk we will identify the important parameters influencing acquisition and quantification of DWI, with emphasis on the choice of b-values and geometrical accuracy. We will discuss the implications when using DWI for extracranial radiotherapy. Finally we will look into possible solutions and provide a framework to ensure maximal exploitation of the imaging technique for the future.

Joint Symposium: ESTRO-IAEA: Joint ESTRO-IAEA efforts on dosimetry, QA and audit for advanced treatment techniques

SP-0027

New IAEA-AAPM Code of Practice for dosimetry of small photon fields used in external beam radiotherapy

H. Palmans[1,2]
[1]*National Physical Laboratory, Acoustics and Ionising Radiation, Teddington, United Kingdom*
[2]*EBG MedAustron GmbH, Medical Physics, Wiener Neustadt, Austria*

Increased use of small photon fields in stereotactic and intensity modulated radiotherapy has raised the need for standardizing the dosimetry of such fields using procedures consistent with those for conventional radiotherapy. While many problems of small field dosimetry have been raised in the past, e.g. in Report 103 of the Institute of Physics and Engineering in Medicine, a vast amount of literature has addressed most of those and solutions have been proposed for specific situations. What has hampered the development of a Code of Practice until recently was the availability of data but in the last few years a considerable number of publications have provided new data and insights that have enhanced our understanding of small field dosimetry.
An international working group, established by the International Atomic Energy Agency (IAEA) in collaboration with the American Association of Physicists in Medicine (AAPM), has finalised a Code of Practice for the dosimetry of small static photon fields. The Code of Practice consists of six chapters and two appendices. The first chapter provides an introduction to situate the distinct role of this Code of Practice as compared to previous recommendations for reference dosimetry in external beam radiotherapy. The second chapter provides a brief discussion of the physics of small photon fields with emphasis on those aspects that are relevant to understanding the concepts of the Code of Practice. Particular issues that are addressed are the definition of field size, the field size dependent response of detectors, volume averaging, fluence perturbation corrections, reference conditions and beam quality in non-conventional reference fields. The third chapter introduces all details of the formalism used, which is based on the IAEA-AAPM formalism published by Alfonso et al. (Med Phys 35:5179-5186, 2008) and is extended to clarify its application to flattening-filter-free beams (FFF beams). The fourth chapter provides a comprehensive overview of suitable dosimeters for reference dosimetry in the conventional 10 cm x 10 cm reference fields, for reference dosimetry in machine-specific reference fields at machines that cannot establish a conventional 10 cm x 10 cm reference field and for the determination of field output factors in small fields. The fifth chapter gives practical recommendations for implementing reference dosimetry in both conventional 10 cm x 10 cm